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Defect Specific Penetrants

R. L. Crane
United States Air Force

S. Allinikov
United States Air Force

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Abstract

The failure to detect small through-the-thickness flaws in non-metallic coatings on metallic substrates can lead to corrosion rates several orders of magnitude greater than those of the bare metal. Therefore, the detection of such defects has high priority even though presently used inspection procedures are both expensive and difficult to perform. It has recently been shown that it is possible to make a penetrant that can detect those through-thickness flaws to the exclusion of all others. These penetrants are made by adding chelating agents to a carrier fluid such as an alcohol. The chelating agent becomes fluorescent when it contacts a metal substrate. Initial work utilized the chelating agent 8-hydroxy quinoline, and is sensitive to most metals. Current work is concentrating on chelating agents that are specific to certain metals. Thus, cracks in chromium coatings or steel can be detected if they penetrate on the steel base. Work on organic and biological agents show promise.

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DEFECT SPECIFIC PENETRANTS

R. L. Crane and S. Allinikov
Air Force Materials Laboratory
Dayton, Ohio 45433

ABSTRACT

The failure to detect small through-the-thickness flaws in non-metallic coatings on metallic substrates can lead to corrosion rates several orders of magnitude greater than those of the bare metal. Therefore, the detection of such defects has high priority even though presently used inspection procedures are both expensive and difficult to perform. It has recently been shown that it is possible to make a penetrant that can detect those through-thickness flaws to the exclusion of all others. These penetrants are made by adding chelating agents to a carrier fluid such as an alcohol. The chelating agent becomes fluorescent when it contacts a metal substrate. Initial work utilized the chelating agent 8-hydroxy quinoline, and is sensitive to most metals. Current work is concentrating on chelating agents that are specific to certain metals. Thus, cracks in chromium coatings or steel can be detected if they penetrate on the steel base. Work on organic and biological agents show promise.

The failure to detect very small through-the thickness flaws in coatings on metal surfaces can result in corrosion rates several orders of magnitude greater than those for the bare metal.[1] Therefore the detection of these defects has a high priority, even though the inspection procedures currently in use are both expensive and difficult to perform. The recent development of a very sensitive penetrant which detects only corrosion initiating flaws could greatly simplify the inspection of coated metal components.[2]

The penetrants described in this article are based on the unique action of some organic compounds which chelate or combine with metal atoms and form fluorescent compounds. In the chelating process the organic molecule reacts with small amounts of metal by attaching itself to a metallic ion to form an organo-metallic complex. The ion is usually held at the center of this coordination complex making the structure rigid. This alters the fluorescent spectra of the original molecule, many times moving it into the visible spectrum. This action of chelating agents has been known for some time and is used to trace element analysis.[3]

Two distinctly different organic compounds were used in experiments to demonstrate the viability of this concept. The first compound, 8-hydroxy quinoline, was added in small amounts (0.1 to 1.0 weight percent) to isopropyl alcohol which served as carrier fluid. This material was applied to the surface of a boron epoxy F-4 rudder. Since this structure contains an aluminum honeycomb, any flaw that would permit water entry to the core could be detected with the penetrant. In the part examined, one flaw did exist and was detected as shown in Fig. 1.

Alcohol dehydrogenase, which is specific to zinc when converted to the apoenzyme form, was used to demonstrate the viability of using biological compounds as chelating agent in penetrants. Alcohol dehydrogenase is a metalloenzyme that contains zinc. The zinc atom can be removed from the protein structure by dialysis at pH of 5.5. This yields a zinc specific chelating agent. The specific action of the compound was tested by dissolving it in water and ethyl alcohol. When this fluid was exposed to zinc powder a faint yellow fluorescence was noted. Other enzymes contain different metal atoms and it may be possible to alter these protein structures to make iron, copper, etc. specific penetrants.

Several characteristics of these defect specific penetrants should be noted. First, they can be both inexpensive and easy to use. Second, the chelating agents are quite sensitive and must not contact their activators prior to use, i.e. the carrier fluid for the quinoline penetrant cannot be stored in a steel can. Third, they appear to be safe for human handling and in the case of the quinoline material, it has been used by law enforcement agencies to check criminal suspects for trace metal contamination.[4] Fourth, the dry fluorescence is often times much brighter than the wet fluorescence. Fifth, the fluorescence is visible only under proper ultraviolet illumination; in these experiments a Magnaflux ZB-26 light source was used. There are no doubt many other peculiarities to be noted in the use of this class of penetrants, and they will be reported in future work.

A new class of defect specific penetrants has been discussed. Two possible penetrant formulations were investigated, one based on an organic substance and the other based on a biological material. While it seems quite easy to detect through-the-thickness flaws in nonmetallic coatings on metal substrates, the design of penetrants that are activated by specific metals requires further work. Future work in this area should enumerate many possible specific penetrants, thus providing penetrants that provide the information about the depth as well as the length of surface connected flaws.

References

1. Evans, Ulick R., An Introduction to Metallic Corrosion, Edward Arnold Lt., London, 1963.
2. Crane, R. L., "A New Penetrant for Composite and Adhesively Bonded Structures," Materials Evaluation Vol. 35, No. 2, p. 54-55, 1977.
3. Welcher, F. J., ed., Standard Methods of Chemical Analysis, 6th edition Van Nostrand Co., New York, 1962.
4. "Trace Metal Detection Techniques in Law Enforcement," Pamphlet issued by the National Institute of Law Enforcement and Criminal Justice, 1970.

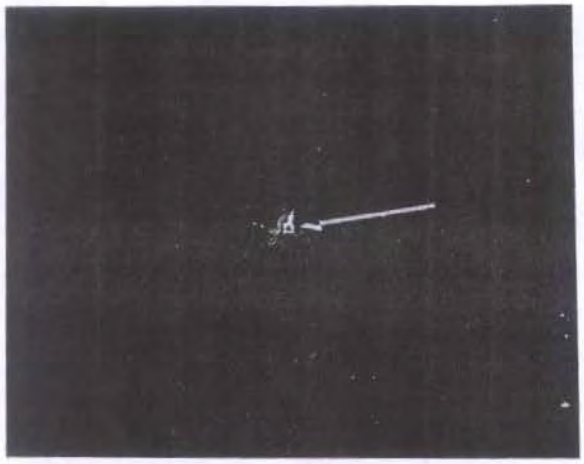

Figure 1. An indication of a through-the-thickness pore in the boron composite skin on an F-4 rudder. The extraneous indications are due to fingerprints.